United States Army School of Aviation Medicine
Fort Rucker, Alabama
August 2003

LESSON PLAN

TITLE: Noise in Army Aviation

FILE NUMBER: U3004517

PROPONENT FOR THIS LESSON IS:

United States Army School of Aviation Medicine
ATTN.: MCCS-HAF
Fort Rucker, Alabama 36362-5000

FOREIGN DISCLOSURE RESTRICTIONS: The materials contained in this lesson plan (LP) have been reviewed by the instructor/training developer and determined to be public domain materials. This product is releasable to military students from all requesting foreign countries without restrictions.

Noise in Army Aviation
U3004517 / Version 1
19 Aug 2003

Prerequisite Lesson(s)

Lesson Number	Lesson Title
None	

Clearance Access

Security Level: Unclassified
Requirements: There are no clearance or access requirements for the lesson.

Foreign Disclosure Restrictions

FD5. This product/publication has been reviewed by the product developers in coordination with the USASAM foreign disclosure authority. This product is releasable to students from all requesting foreign countries without restrictions.

References

Number	Title	Date	Additional Information
0-7817-2898-3	Fundamental of Aerospace Medicine, 3rd Edition		
AR 40-501	Standards of Medical Fitness	30 Sep 2002	
FM 3-04.301	Aeromedical Training for Flight Personnel	29 Sep 2000	
TB MED 501	(SS/DA Pam 40-501, Aug 91) Occupational & Environmental Health:Hearing Conservation	15 Mar 1980	
TG 170	(SS/DA Pam 40-501) Hearing Conservation		

Student Study Assignments

Study student handouts and required reference materials

Terminal Learning Objective

NOTE: Inform the students of the following Terminal Learning Objective requirements.

At the completion of this lesson, you [the student] will:

Action:	Manage the effects of noise and vibrations in Army aviation
Conditions:	
Standards:	IAW FM 3-04.301 (FM 1-301), AR 40-501, DA PAM 40-501 and Fundamentals of Aerospace Medicine

Safety Requirements

None

Risk Assessment Level	Low
Environmental Considerations	**NOTE:** It is the responsibility of all soldiers and DA civilians to protect the environment from damage. None

A. ENABLING LEARNING OBJECTIVE

ACTION:	Manage the effects of noise in Army Aviation
CONDITIONS:	While performing as an aircrew member.
STANDARDS:	IAW FM 3-04.301 (FM 1-301), AR 40-501, DA PAM 40-501 and Fundamentals of Aerospace Medicine

1. Learning Step / Activity 1. Define Sound

a. The nature of sound.

(1) Sound is the mechanical radiant energy that is transmitted by longitudinal pressure waves in a medium such as air and is the objective cause of hearing.

(2) Sound is produced when an object or surface vibrates rapidly and generates a pressure wave or disturbance in the surrounding air.

EXAMPLE**:** Air is a springy, elastic substance composed of molecules. The elasticity is due to the tendency of these molecules to spring back to their original position of rest whenever they are deflected or displaced by an outside disturbance or force. As sound waves travel through the air, the pressure fluctuations cause the molecules to vibrate back and forth from their normal positions at rest. In doing so, they bump other molecules, imparting motion to them and then, rebounding back and forth, and returning to their original positions.

(3) Colliding molecules produce vibration pressure increases or a “compression;” molecules rebounding away from each other produce a lower pressure or a “rarefaction.”

(a) Sound can be transmitted through any elastic substance such as air, water, or bone.

(b) The density of the substance determines the speed at which the sound and pressure waves will travel. The denser the substance, the faster and longer the sound will travel.

(4) The high speed of the rotor blade compresses the air faster than the ability of the high-pressure disturbance to flow away.

b. To better understand why Army aviation personnel lose their hearing, it is important to understand the mechanism of hearing. Hearing is the perception of sound. Sound and pressure waves must pass through three areas of the ear before the brain perceives them.

(1) The external ear is the visible portion of the ear and the external auditory canal, which ends at the eardrum. Sound is transmitted by air in this portion of the ear.

(2) The middle ear is the small, air-filled cavity that separates the external and inner ear. Three small bones or ossicles, which are the malleus, incus and stapes (hammer, anvil, and stirrup), link the eardrum to the inner ear and mechanically carry sound to the hearing receptors. The Eustachian tube

connects the middle ear with the nose and permits drainage and ventilation of the middle ear. It also equalizes pressure between the outside ear and the middle ear.

(3) The inner ear is the third component that lies deep within the temporal bone. It consists of two sections. The vestibular section which senses balance. The auditory portion, which is the cochlea, is comprised of a fluid-filled chamber where the hair-like receptors for hearing are located. The movement of the ossicles causes hydraulic movement of the fluid. The hair cells detect this fluid movement and transmit electrical impulses to the brain where sound is interpreted.

(a) Sound of any type generates movement of fluid that stimulates the hair cells to convert mechanical impulses into electrical impulses. Loud sounds may fatigue these cells to the point where it may take several hours of relative quiet before they can revert to their normal state.

EXAMPLE: Hair cells can be compared to blades of grass. Walking on the grass causes it to bend, but then it rings back over time. However, if you walk on the grass continuously, the grass will no longer spring to life. Hair cells damaged from prolonged exposure to noise will not spring back.

(b) Hair cells are grouped into bundles. Destroyed hair cells in the various bundles means loss of sound perception.

2. Learning Step / Activity 2. Identify the effects of noise

a. Noise is defined as sound that is loud, unpleasant, or unwanted, however, the sound does not have to be loud to be considered a noise. It is contingent on how the listener perceives it. In aviation, noise could cause annoyance, speech interference, fatigue and hearing loss.

b. Annoying noise can affect pilots while they are performing their duties because it interferes with concentration.

c. Fatigue can be caused by a number of physiological responses that have been attributed to noise. Reported responses include the effects of blood flow to the skin, respiration, skeletal muscle tension, and constipation.

d. Speech interference occurs when noise masks and obscures words.

e. Hearing loss can occur due to exposure to noise that is above safe limits and damage may be either temporary or permanent. The bottom line is that over exposure to noise destroys your hearing.

3. Learning Step / Activity 3. Identify the three measurable characteristics of noise

a. Noise has measurable characteristics.

(1) Frequency is the physical characteristic that gives sound its subjective quality of pitch. Frequency of periodic motion is the number of times per second the air pressure oscillates. The number of oscillations, or cycles per second, is measured in hertz (Hz).

(a) Human hearing range. The human ear is very sensitive and can detect frequencies from 20 to 20,000 Hz.

(b) Human speech range. Speech involves frequencies from 200 to 6,800 Hz. This is the range to which the ear is most sensitive.

(c) Speech intelligibility. You must be able to hear in the range of 300 to 3000 Hz to understand speech communication.

(2) Intensity is the physiological correlation of sound intensity or pressure to loudness. For auditory measurement it is convenient to convert the physical measurement of intensity to a logarithmic scale known as the decibel (dB) scale.

(a) dB ranges of the human ear.

1) 0 dB. Close to the human hearing threshold or the smallest sound heard by the average normal human ear. It is not the absence of sound.

2) 65 dB. Average level of conversational speech with moderate level of vocal effort

3) 85 dB. Level of steady noise that is considered hazardous regardless of the duration, hearing conversation measures must be taken when exposed to noise level at or above 85 dB.

4) 120 dB. Known as the discomfort threshold. This level of noise is uncomfortable to the human ear.

5) 140 dB. Level of noise that will produce pain in the average human ear, known as the pain threshold

6) 160 dB. Physical damage may result at this level of noise. The eardrum may rupture and the noise (pressure) may be forceful enough to disrupt the ossicles in the middle ear.

(b) Sound pressure increases with more intense noise.

1) Since the decibel is a logarithmic ratio, a 20 dB increase equals a pressure increase of 10 times.

2) The entire range of human hearing from 0 dB to 140 dB shows a 10 million fold increase in sound pressure.

(3) Duration is characterized as how long you are exposed to noise.

(a) Steady noise is sound without intermittence or significant variability in overall intensity for prolonged periods of time. This is the most common type of noise experienced in Army aviation and it originates primarily from engines, drive shafts, transmissions, rotors and propellers.

(b) Impulse noise is a type of sound characterized by explosive noise that builds up rapidly to a high intensity peak and fall off rapidly. This entire cycle is usually measured in milliseconds. Defined as less than 1 second in duration.

b. Army noise exposure criteria. The Surgeon General has established 85 decibels as the maximum permissible sound level of continuous unprotected exposure to steady-state noise for 8 hours.

(1) The following table shows the recommended allowable sound intensities for the various duration of exposure:

Exposure Duration Per Day (HRS)	Maximum Exposure Level (dB)
8	**85**
4	**90**
2	**95**
1	**100**
1/2	**105**

(2) For every 5 decibels noise intensity increase, the exposure time is cut in half.

CAUTION: Unprotected exposure to noise levels in excess of 85 dB can result in temporary or permanent hearing loss. Air crewmembers must use hearing protection to prevent hearing loss.

4. Learning Step / Activity 4. Identify the types of hearing loss associated with prolonged exposure to noise.

a. Hearing loss depends on several factors such as age, individual's health, and the environment (lifestyle).

(1) Conductive hearing loss occurs when there is a defect or impediment in the external or middle ear. This may be caused by wax, fluid, or calcification, which impedes the mechanical transmission of sound to the inner ear. In most cases it can be treated medically.

(2) Sensorineural hearing loss occurs when the cochlea is damaged. It is most frequently produced by noise, but can also be caused by heredity, disease, and aging (Presbycusis). This hearing loss is permanent and usually occurs in the higher frequencies first. Substantial loss may occur before the speech frequencies are affected; there is no medical treatment for this type of loss; hearing aids may be beneficial.

(a) Acoustic trauma. This type of damage to the ear is sudden and may cause temporary or permanent hearing loss.

1) Acoustic trauma is caused by high intensity impulse noise. It can be single or repetitive in nature with the duration generally measured in milliseconds.

2) Usually in excess of 140 dB.

3) Impulse noise (blast, gunfire, etc.) is usually predictable; therefore, acoustic trauma is usually preventable.

(3) Mixed hearing loss. Is the combination of conductive loss and sensorineural loss. An air crewmember with high frequency hearing loss with a middle ear infection will have conductive component that is treatable and sensorineural loss that is not.

b. Noise induced hearing loss (NIHL)

(1) Temporary Threshold Shift (TTS) results from a single exposure to a high level noise. Threshold shifts may last for a few minutes or for a few hours, the duration of the shift depends primarily upon the duration, intensity, and frequency of the noise exposure. Recovery, when noise is removed, is usually complete.

(2) Permanent Threshold Shifts (PTS) is the shift that occurs when exposed to continued noise for 15 hours could eventually result to permanent loss. Recovery does not occur even though the noise exposure is terminated. Temporary threshold shifts eventually become permanent. This process cannot be predicted.

5. Learning Step / Activity 5. Identify the characteristics of noise induced hearing loss

a. Noise induced hearing loss is insidious because it is usually undetectable, painless and very gradual.

b. Prolonged exposure to noise of moderate intensity may cause temporary and eventual permanent hearing loss.

c. Noise intensity usually below 140dB, but above 85 dB.

d. Physical pain is usually not evident and there are often no symptoms whatsoever of any hearing loss.

e. Initially, the higher frequencies of hearing are lost. When this becomes severe enough to interfere with speech communications, the individual will lose the ability to understand the sounds of consonants in words. Consonants consist of sounds in a higher frequency range than vowels. In the earlier stages communications becomes difficult in the presence of background noise.

f. How can you tell your hearing has been affected? Through testing, your initial audiogram is considered a reference audiogram. All subsequent audiograms will be measured against the initial reading.

(1) Audiograms are considered normal as long as hearing thresholds are 20 dB or less for all frequencies tested. The acoustic notch begins with a drop in hearing in the 3000-4000 Hz range, with recovery at 6000 Hz.

(2) The following table shows the maximum acceptable audiometric hearing levels for Army aviation:

Frequency (Hz)	500	1000	2000	3000	4000	6000
Classes 1/1a	25	25	25	35	45	45
Classes 2/3/4	25	25	25	35	55	65

(3) Only physicians and audiologists can diagnose noise induced hearing loss.

(4) Audiograms can detect inaccurate readings and will re-test the subject until normal patterns of audiometry are achieved.

6. Learning Step / Activity 6. Identify the noise characteristics of military aircraft

a. Looking at Army aircraft as both fixed and rotary wing, certain generalizations can be made.

(1) Overall noise levels generally are equal to or exceed 100 dB. This exceeds the average 85 dB damage risk-criteria.

(2) The frequency that generates the most intense level is 300 Hz. Low frequency noise will produce a high frequency hearing loss. Providing adequate hearing protection for lower frequencies is very difficult due to the way lower frequencies are transmitted (vibrations).

(3) Exposures to these levels without hearing protection will lead to definite permanent noise induced hearing loss.

b. Noise in Army fixed wing aircraft originates from power plants, propellers, and transmissions. Their noise levels will depend on the following criteria:

(1) Location of the engines and their proximity to the cockpit.

(2) How much insulation do they have?

(2) The table below shows peak noise levels for Army fixed wing aircraft currently in service:

Aircraft	dB
C-12 / RC-12	* 106
UC-35	** 96

NOTES: *Exterior noise level, ** Cabin noise level

c. Noise in Army rotary wing aircraft originates from power plants, rotor systems, and transmissions that produce significant pure tone narrow bandwidth noise.

(1) Observation helicopters are small in size but could generate an extreme amount of noise with levels exceeding 100 dB.

(2) Attack helicopters such as the AH-64 Apache is a closed cockpit helicopter, the rear seat occupant is exposed to engine noise at close proximity. Weapon systems can add more noise during mission profile.

(3) Utility and cargo helicopters noise levels fluctuate with cargo doors and ramps open. Troops that are being airlifted should wear hearing protection. Air crewmembers must ensure that passengers wear hearing protection while inside the troop/cargo compartment.

(4) The table below shows Army rotary wing aircraft and their peak noise levels:

Aircraft	dB
UH-1H	**102**
AH-1S	**105**
OH-58C	**103**
OH-58D	**100**
CH-47D	**112**
UH-60A	**108**
AH-64	**104**
***TH-67**	**102**

NOTE: * Noise level for TH-67 based on noise level for a BELL 206 helicopter.

d. Noise in Air Force cargo aircraft. Due to our worldwide mission, air crewmembers may have to rely on cargo fixed wing aircraft to transport their aircraft to distant locations around the world.

(1) Noise levels on cargo aircraft can exceed 85 decibels during air load operations on the ground.

(2) As passengers, crewmembers could be exposed to noise levels well above the damage risk criteria.

(3) The table below shows the noise levels that crewmembers are exposed to during operations in or around heavy lift aircraft:

Aircraft	Maximum	Pilot-Cruise
C-5A	107 dB	85 dB
C-141	94 dB	84 dB
C-130	95 dB	84 dB
C-17	90.7 dB	89.5 dB

(4) During air load operations, ensure that yourself and aircrews wear hearing protection to minimize the potential for hearing loss.

7. Learning Step / Activity 7. Identify the most practical and economical method of noise reduction available to aircrew members

a. A number of methods of protecting human hearing and/or controlling noise are available. Some methods are not economically feasible; others are not suitable for operational requirements. The following major methods of controlling noise must be considered.

(1) Design or plan to eliminate the noise. This is the ideal way of controlling noise.

EXAMPLE: Design a new type aircraft with decreased noise levels.

(2) Isolate the noise source. Increasing the distance between the noise source and the exposed person can accomplish this.

EXAMPLE: Move auxiliary power units away from work areas.

(3) Enclose the noise source. This can be accomplished by using sound and energy absorbent material (baffling).

EXAMPLE: Increase amount of insulation in the cockpit and cabin area.

(4) Personal protective devices. These are the most practical and economical methods available for noise protection. A number of devices are available to attenuate (reduce) the noise at an individual's ears.

(a) Personal protective measures have certain distinct characteristics.

1) Attenuation is the amount of noise protection provided by a specific protective device. The attenuation of any given noise protective device is the number of dB it reduces from the total energy reaching the eardrum.

2) Speech intelligibility and other acoustic signals are better understood in noisy environments when noise protective devices are utilized. This is due to an increase in the signal to noise ratio brought about by a reduction in the masking effect of the noise.

3) Maximum attenuation. Maximum attenuation for any device is approximately 50 dB. At this point sound is transmitted to the inner ear by bone conduction (vibration).

(b) Types of personal protective measures.

1) Ear plugs. Foam, single flange, and triple flange; these devices are inserted into the external ear canal. They are inexpensive, easy to carry, and effective when fitted properly.

CAUTION: Ensure that your hands and earplugs are clean prior to insertion into the ear canal to eliminate ear infection.

a) They provide attenuation from 18-45 dB across the frequency band.

b) They should be worn anytime you are exposed to noise levels in excess of 85 dB. They are very effective when worn in conjunction with the SPH-4, SPH-4B, HGU-56, and IHADSS flight helmets.

2) Ear muffs. These devices are worn covering the ear. They provide 10-41 dB protection, across the frequency band, are comfortable, and because they can be readily seen, managerial control for wearing hearing protection is enhanced. Do not forget ground personnel or your passengers. They are subject to hearing loss just as well as crewmembers.

3) Headsets. These devices are worn covering the ears, but also provide radio communication. Commonly worn in VIP type aircraft. Noise attenuation can be degraded due to rough handling, abuse, improper fits, and deteriorated ear seals. Headsets lack the crash attenuation provided by a helmet.

4) Protective helmets.

a) For aviators and crewmembers, this is the best means of personal protection. They provide both noise and crash attenuation. The SPH-4B, HGU-56, and IHADSS provide greater protection in the higher frequencies. However, it is low frequency noise in the aviation environment that is the cause for concern.

b) The helmet is an excellent hearing protection device. It will provide optimal protection only if certain guidelines are followed:

- It must fit properly.

- It must be worn correctly.

- The ear cup seals must be soft, unwrinkled, and tear free. When the seals harden, they must be replaced.

c) If the SPH-4B, HGU-56, and IHADSS helmets are worn properly, the noise attenuation brings the noise exposure within the confines of the damage risk criteria for every aircraft except the **UH-60, and CH-47D.**

d) The table below shows aircraft and helmets attenuation levels without wearing earplugs:

Aircraft	Hearing Protector	Effective Exposure Level
AH-1S	HGU-56 SPH-4B SPH-4	77.0 77.4 83.2
UH-1H	HGU-56 SPH-4B SPH-4	81.3 81.0 85.9
OH-58D	HGU-56 SPH-4B SPH-4	81.6 81.5 86.3
OH-58C	HGU-56 SPH-4B SPH-4	76.9 76.8 81.4
UH-60A	HGU-56 SPH-4B SPH-4	90.6 90.6 95.1
CH-47D	HGU-56 SPH-4B SPH-4	86.8 88.0 93.4
AH-64	IHADSS (REG) IHADSS (XL)	80.2 83.5
C-12	H-157 Headsets	70.5

e) The polymeric foam (EAR) hand formed earplug in combination with the SPH-4B, HGU-56, and IHADSS helmets will provide additional protection from all aircraft noise in the US Army inventory.

f) The table below shows exposure levels when wearing both SPH-4 helmet with three types of earplugs at pilot's station for various aircraft:

Protector	**UH-60A** 120 knots	**CH-47D** 100 knots	**AH-1S** 100 knots	**OH-58** 100 knots	**UH-1H** 100 knots
SPH-4 with triple flange plug	72.6	77.5	70.2	65.7	70.7
SPH-4 with single flange plug	75.3	78.4	71.5	67.4	71.9
SPH-4 with foam plug	70.4	77.3	68.8	63.5	68.8

g) SPH-4B helmets attenuation levels when worn with earplugs are 1 to 2 dB lower for each aircraft indicated above.

h) HGU-56 helmets attenuation levels when worn with earplugs are 2 to 3 dB lower for each aircraft indicated above.

b. You may find that your ability to hear communications in the cockpit is diminished while using earplugs for the first time. This is due to the fact that your subconscious is adjusting to the lower sound intensity. You may feel that you have to concentrate and listen more closely to the transmissions. Once you get used to listening with the earplugs in place, you will find it easier to hear.

c. Communications Ear Plugs (CEP) is a device used to improve hearing protection and speech reception communication. It includes a miniature transducer that reproduces speech signals from the internal communication system (ICS). The foam tip acts as a hearing protector, similar to the yellow foam earplugs pilots wear for "double hearing protection". A miniature wire from the CEP connects to the communications system through the mating connector mounted on the rear of the helmet. CEP has recently (July 1999) been issued its airworthiness release (AWR) for all U.S. Army Aircraft using the SPH-4 or HGU-56P helmets, and for the M45 Aircrew Protective Mask (ACPM) for all U.S. Army Aircraft using the M24 mask. This communication device has been enthusiastically received within the tested pilot population. This product is not yet in the federal stock system. One of the advantages of the CEP's is that if there is a malfunction of the device, the aircraft communications can still be used.

8. Learning Step / Activity 8. Identify the sources on non-occupational noise exposure

a. Noise does not end at the flight line; thus our ears often never get the chance to recuperate from the noise exposure associated with flying. Aviators must be aware of the sources of potentially damaging noise exposure and take appropriate action to minimize these exposures.

b. General aviation. Many aircrews have civilian private or commercial pilot certificates or instructor pilot ratings. They may fly for pleasure or additional income. This is an extremely critical source of exposure, since most private aircraft are flown without headsets, relying on speakers for hearing voice communications. Most single-engine light aircraft have noise levels in excess of 85 dB below 1000 Hz, which requires noise protection. Unprotected, air crewmembers could suffer noise induced hearing loss.

c. Weapons firing. This applies to several categories of weapons firing. Unprotected, these impulse noises can result in sustained acoustic trauma. Some high velocity small arms weapons have peak intensities in excess of 168 dB. All small arms in the Army produce impulse noise levels above 140 dB. Noise protection should be used whenever air crewmembers are engaged in weapons firing. Some sources of indirect or non-occupational exposure are:

(1) Hunting, skeet or target shooting.

(2) Annual weapons qualification.

d. Moonlighting. A variety of off-duty jobs may expose the air or ground crewmen to additional potentially harmful noise exposures.

(1) Bartending (95-110 dB), in a club where loud music is played.

(2) Members of a “rock” band (110-150 dB).

e. Contemporary music. Frequently aircrews will innocently expose themselves to extremely loud and sustained levels of noise via music. Surveys in Officer's and NCO clubs have revealed exposures and intensity levels that exceed 130 dB. This exposure has also shown to produce permanent hearing loss.

(1) Personal portable radios aim high noise levels directly into the ear canal.

(2) Portable stereo systems "boom boxes."

f. Hobbies and recreation. Often hobbies and recreation result in innocent and thoughtless exposure.

g. Household chores. Even the simplest household equipment can expose you with unnecessary noise.

(1) Lawnmowers (95-100 dB).

(2) Vacuum cleaners (90-100 dB).

(3) Blender (93 dB).

(3) Hair dryer (80 dB).